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Yield Response of Maize (*Zea mays* L.) and Sesame (*Sesamum indicum* L.) Intercrop as Influenced by Planting Densities and Varieties of Sesame at Makurdi, Nigeria

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ABSTRACT

A field experiment was conducted from July to October, in years 2014 and 2015 at the Research Farm, University of Agriculture, Makurdi, Nigeria, to evaluate the yield response of maize-sesame intercrop as influenced by planting densities of sesame and varieties of sesame, as well as to assess the yield advantages of the intercropping system. The factorial (3 x 3) combinations of the treatments were randomly arranged in a split-plot design, with four replications. The varieties of sesame (Ex Sudan, SN 603 and E-8) into maize constituted the main plots, while the planting densities of sesame (66,666, 88,888 and 133,333 plants ha^{-1} equivalent) into maize were assigned to the subplots. Results of study showed that intercropping maize with sesame variety 'Ex Sudan' produced the highest grain yield for maize and highest seed yield of 0.45 t ha^{-1} and 0.33 t ha^{-1} respectively, in years 2014 and 2015 for sesame. Sesame sown into maize at the density of 66,666 plants ha^{-1} produced the highest maize yield of 3.6 t ha^{-1} and 3.8 t ha^{-1} respectively, in years 2014 and 2015 and highest sesame yields in both years. Intercropping sesame variety 'Ex Sudan' into maize at the density of 66,666 plants ha^{-1} also gave the highest total intercrop yields, highest land equivalent coefficient (LEC) values, highest land equivalent ratio (LER) values of 1.83 and 1.80, highest percentage (%) land saved, lowest competitive ratio and lowest aggressivity. The implication of study showed that it is most advantageous having both crops in intercrop when sesame variety 'Ex Sudan' was sown into maize at the density of 66,666 plants ha^{-1}. This should therefore be recommended for Makurdi location, Nigeria.

***Keywords*:** maize; sesame; intercropping; planting densities; varietal trials; Nigeria

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) commonly known as beniseed is one of the world's oldest spice and oil seed crop of the family Pedaliaceae and cultivated in the tropics and temperate zones of the world (Bedigan, 2003). The crop is believed to have originated from Africa, probably in Ethiopia and spread to India, were secondary centre of diversity developed (Onwueme and Sinha, 1991). The major sesame growing countries are China, India, Mexico and Sudan. India and China are the world's largest producers of sesame (FAO, 2008).

Nigeria is the third largest producer of sesame in Africa after Sudan and Uganda (Olowe *et al*., 2007). The country is classified among the sesame exporting countries of Africa (Weiss, 2000). World production of the crop stood at 2,014,000 tonnes per year in 1993 (Burden, 2005), while sesame production in Nigeria was estimated to be over 60,000 tonnes as at 1995 (Weiss, 2000). It is grown mainly for its seed that contains 50 % oil and 25 % protein (Burden, 2005). It is used in the manufacture of margarine, toilet soaps, fine grade machine oil and pharmaceuticals. The roots and leaves are used in treating migraine, hypertension, ulcers, constipation, chicken pox and piles (Odugbemi, 2006).

Maize (*Zea mays* L.) is Nigeria's third most important cereal crop following sorghum and millet (Uzozie, 2001). It is grown for its grain which contains 65 % carbohydrate, 10-12 % protein and 4-8 % fat (Iken and Amusa, 2004). The crop also contains the vitamins A, B, C and E, including mineral salts and essential trace elements such as carotene, thiamine, ascorbic acid and tocopherol (Groote, 2002). Worldwide, about 65 % of maize plant is used for feeding livestock, 25 % for human consumption and 10 % for industrial uses and seeds (Fisher and Palmer, 1984).

Though, studies on areas such as varietal response (Adeyemo *et al*., 1992; Adeyemo and Ogunwolu, 1996) and population densities (Adeyemo *et al*., 1992), amongst many others as it affects sesame production have focused mainly on sole cropping, however, there is dearth of information on the yield response of sesame, as well as the suitability and compatibility of sesame varieties to intercropping with cereal crops, particularly maize. The experiment therefore aimed at evaluating the yield response of maize-sesame intercrop as influenced by varieties and planting densities of sesame, with the objectives to:

1. Identify the best sesame variety that will produce optimal intercrop yields of maize and sesame.
2. Identify the optimal planting density of sesame in a maize-sesame intercrop.
3. Assess the yield advantages of intercropping maize-sesame mixture as influenced by planting densities of sesame and varieties of sesame.

2. MATERIALS AND METHODS

2. 1. Experimental site

The experiment was conducted from July to October, in years 2014 and 2015, at the University of Agriculture Teaching and Research Farm, Makurdi, Nigeria, to evaluate the yield response of maize-sesame intercrop as influenced by varieties and planting densities of sesame. The meteorological information of the study area for years 2014 and 2015 were collected from the Air Force Base Meteorological Station, Makurdi (Table 1). Soil samples were collected from the different parts of the experimental field. The composite sample was used to determine the physical and chemical properties of the soil before planting (Table 2).

2. 2. Sources of planting materials

The variety of maize used was Downy mildew early streak resistant-white (DMESR-W). Three sesame varieties (Ex Sudan, SN 603 and E-8) were used. 'Ex Sudan' and 'SN 603' are improved varieties, obtained from the West African Seed Alliance, Abuja, Nigeria. Sesame variety 'E-8' is a local variety, popularly grown by farmers in Makurdi, Nigeria.

2. 3. Experimental design, plot size and treatments

The factorial (3 x 3) combinations of the treatments were randomly arranged in a split plot design, using four replications. The varieties of sesame and that of maize constituted the main plots, while the planting densities of sesame (66,666, 88,888 and 133,333 plants ha^{-1} equivalent) into maize were assigned to the subplots. The experimental area cultivated was 607.5 m^2 (approximately 0.06 ha equivalent), and consisted of 52 treatment plots (subplots). Each plot had an area of 9.0 m^2.

2. 4. Land preparation and planting

The experimental field was cleared, ploughed, harrowed and ridged. Each plot consisted of 4 ridges. In sole maize plot, each ridge consisted of 10 maize stands, at an intra-row spacing of 30 cm. A total of 40 maize stands were sown in each plot (44,444 maize stands ha^{-1} equivalent). In the sole sesame plot, 15 sesame stands were sown on a ridge at an intra-row spacing of 20 cm (Ijoyah *et al*., 2014), giving a total of 60 sesame stands per plot (66,666 sesame stands ha^{-1} equivalent). In the sole plots, maize and the three varieties of sesame were planted in a single row on top of the ridge, at their recommended planting densities, while in the intercrop plots, maize was sown in a single row on top of the ridge, while sesame was sown by the side of the ridge, but at the varied planting densities.

2. 5. Cultural practices

Weeding was done with the native hoe as the need arose. The recommended rate of compound fertilizer NPK (15:15:15) for sole maize: 100 kg N ha^{-1}, 40 kg P ha^{-1} and 60 kg K ha^{-1}; for sole sesame: 30 kg N ha^{-1}, 30 kg P ha^{-1} and 30 kg K ha^{-1} and for maize-sesame intercrop: 100 kg N ha^{-1}, 100 kg P ha^{-1} and 100 kg K ha^{-1} were applied (Enwezor *et al*., 1989). The band method of fertilizer application was employed. The fertilizer was applied twice to each plot at 3 and 6 weeks after planting (WAP).

2. 6. Harvesting

Maize was harvested at 12 WAP, when the leaves turned yellowish and fallen off, which were signs of senescence and cob maturity (Ijoyah and Jimba, 2012). Sesame was harvested when capsule turned yellowish with shedding of leaves.

2. 7. Data collection

Data were collected on the following:

2. 7. 1. Maize

Days to attain 50 % flowering was taken by counting the number of days from when the crop was sown to when 50 % plants flowered. Plant height (cm) taken at 50 % flowering was measured as the distance from the soil surface to the tip of the topmost leaf (this was obtained from a sample of 4 plants in each plot and averaged). Stem diameter (mm) taken at 6 and 12 WAP. The number of leaves per plant and leaf area index were recorded at 50 % flowering. The number of cobs per plant was taken at maturity (this was done by counting the number of cobs from the sampled plants in each plot and averaged). The cob length and cob diameter at maturity (the diameters at the head, centre and tail ends measured in cm and averaged). The cobs were weighed using an electronic weighing balance to obtain cob weight (g). The total number of cobs for each net plot area was also harvested, shelled and the grains weighed for total yield converted to t ha^{-1}. Thereafter, 1000 grains were taken from the whole bulk of grains and weighed (g).

2. 7. 2. Sesame

Days to attain 50 % flowering, plant height (cm) taken at maturity, number of primary branches per plant at 9 WAP, number of total branches per plant at maturity, number of leaves per plant, number of capsules per branch, number of capsules per plant, length (cm) of capsule, weight (kg) of capsules per plant, number of seeds per capsule, weight (g) of 100 seeds and seed yield (t ha-1).

2. 8. Statistical analysis

Analysis of variance (ANOVA) for split plot was carried out on each observation for each year and the Least Significant Difference (LSD) was used for means separation ($P \leq 0.05$) following the procedure of Steel and Torrie (1980). Main treatment effect and the interaction were also determined.

2. 9. Evaluation of yield advantages in intercropping

The land equivalent ratio (LER) was determined as described by Willey (1985) using the formula:

$$LER = \frac{Intercrop\ yield\ of\ crop\ A}{Sole\ crop\ yield\ of\ A} + \frac{Intercrop\ yield\ of\ crop\ B}{Sole\ crop\ yield\ of\ B}$$

The competitive ratio (CR) as described by Willey and Rao (1980) was determined using the formula:

$$CR = Lm/Ls,$$

where; Lm: Partial LER for maize; Ls: Partial LER for sesame.

The percentage (%) land saved as described by Willey (1985) using the formula:

$$\% \text{ land saved} = 100 - 1/LER \; X \; 100$$

Aggressivity (A) gives a simple measure of how much the relative yield increase in component 'a' is greater than that for component 'b' as described by McGilchrist (1971) using the formula:

$$A = \frac{Mixture\ yield\ of\ 'a'}{Expected\ yield\ of\ 'a'} - \frac{Mixture\ yield\ of\ 'b'}{Expected\ yield\ of\ 'b'}$$

where:
A = 0: indicates that both crops are equally competitive; A = -: indicates dominated component
A = +: indicates dominant component

The land equivalent coefficient (LEC) as described by Adetiloye *et al.*, (1983) was determined using the formula:

$LEC = La \; x \; Lb$; where La: LER of main crop; Lb: LER of intercrop.

These calculations were used to assess the yield advantages of the intercropping system.

3. RESULTS AND DISCUSSION

3. 1. Meteorological information for Makurdi, Nigeria (July-October) in years 2014 and 2015

The meteorological information for Makurdi, Nigeria, during the period from July to October, in years 2014 and 2015 is presented in Table 1. Rainfall was regular from the months of July to October in the two years of study. In both years, the month of August recorded the highest amount of rainfall and highest number of rainy days. In year 2014, the average monthly temperature ranged from 21.5 °C to 31.5 °C, while in year 2015, it ranged from 21.4 °C to 31.7 °C. The average monthly relative humidity was high, ranging from 81.1 % to 86.3 % in year 2014 and from 84.5 % to 85.4 % in year 2015. In each year, the average solar radiation was about 6.0 hours.

3. 2. Physico-chemical properties of the soil of experimental site before planting in years 2014 and 2015

In Table 2, total nitrogen values were low, ranging from 0.07 % to 0.09 % in both years. The soil had a low level of available phosphorus, with a corresponding low level of potassium ranging from 0.22 centimol/kg to 0.26 centimol/kg in both years. The pH in water was slightly acidic to neutral. The textural class of soil was sandy-loam.

3. 3. Growth and yield of sesame in a maize-sesame intercrop as influenced by planting densities and varieties of sesame.

Although days to attain 50 % flowering for sesame was not significantly ($P \leq 0.05$) affected by the varied planting densities of sesame in a maize-sesame intercrop (Table 3), however sesame variety 'E-8' significantly ($P \leq 0.05$) took longer days to attain 50 % flowering as compared to that achieved by the other varieties (Table 1). The difference in the number of days taken to attain 50 % flowering by the sesame varieties could be attributed to varietal response since varieties differ in the length of time they may remain at the vegetative stage before flowering. Sesame variety 'Ex Sudan' was the earliest to attain 50 % flowering (Table 3). Sesame height at maturity and number of primary branches per plant at 9 weeks after planting (WAP) significantly ($P \leq 0.05$) reduced as planting density of sesame increased from 66,666 plants ha^{-1} to 133,333 plants ha^{-1} (Table 3). The reduced sesame height recorded at higher plant densities could be linked to intense competition for available nutrients prompted at higher plant densities. In both years, the tallest sesame plants (143.6 cm and 150.2 cm) were produced from sesame sown at the density of 66,666 plants ha^{-1}.

Sesame variety 'Ex Sudan' produced the tallest heights and highest number of primary branches per plant at 9 WAP (Table 3). These might be due to variation in genetic composition of the variety 'Ex Sudan', and its tolerant response to the prevailing environmental conditions. While sesame variety 'Ex Sudan' sown at the density of 88,888 plants ha^{-1} into maize recorded the earliest days to attain 50 % flowering (Table 4), tallest sesame height and highest number of primary branches per plant at 9 WAP were obtained from sesame variety 'Ex Sudan' sown at the density of 66,666 plants ha^{-1} (Table 4).

Table 1. Meteorological information for Makurdi, Nigeria (July-October), in years 2014 and 2015.

Months	Average monthly rainfall	Average monthly temperature (°C)		Average relative humidity (%)	Average solar radiation (hrs)
2014		**Max.**	**Min.**		
July	274.6 (20)$^{+}$	30.6	21.5	83.2	6.4
August	306.9 (23)	29.4	21.8	86.0	5.8
September	129.3 (13)	30.2	22.0	86.3	5.6
October	100.6 (6)	31.5	22.8	81.1	6.2
2015					
July	223.5 (15)$^{+}$	30.2	21.4	85.2	6.2
August	237.2 (18)	28.5	21.7	84.7	5.7
September	110.0 (12)	31.3	22.1	84.5	5.5
October	92.4 (7)	31.7	23.1	85.4	6.3

$^{+}$Values in parenthesis indicate number of rainy days.
Source: Air Force Base Makurdi, Meteorological Station.

Table 2. Physico-chemical properties of the soil of experimental site before planting, in years 2014 and 2015.

Parameters	Quantity in soil		Method of analysis
	2014	2015	
Organic matter (%)	1.62	1.71	Walkley-black method
Nitrogen (%)	0.09	0.07	Kjeldahl method
P_2O_5 (ppm)	4.4	3.8	Flame photometric
K (centimol/kg)	0.26	0.22	Oxidation method
Sand (%)	76.4	75.5	Hydrometer
Clay (%)	14.2	13.6	Hydrometer
Silt (%)	9.4	10.9	Hydrometer
pH (H_2O)	6.3	6.4	pH meter
pH ($CaCl_2$)	4.6	4.8	pH meter

Type of soil: Sandy-loam
Source: Soil Science Laboratory, University of Agriculture, Makurdi, Nigeria.
ppm: parts per million

Table 3. Main effects of planting densities of sesame and varieties of sesame on days to attain 50 % flowering for sesame, plant height of sesame at maturity and number of primary branches per plant at 9 WAP in a maize-sesame intercrop, in years 2014 and 2015, at Makurdi, Nigeria.

Planting densities of sesame	Days to attain 50 % flowering for sesame		Plant height (cm) of sesame at maturity		Number of primary branches per plant at 9WAP	
	2014	2015	2014	2015	2014	2015
66,666	56.1	56.3	150.2	143.6	3.1	3.2
88,888	54.3	54.7	130.4	126.9	2.4	2.6

133,333	55.6	55.8	92.3	83.6	2.1	2.3
LSD ($P \leq 0.5$)	6.2	4.4	3.4	2.6	0.03	0.02
Varieties of sesame						
Ex Sudan	55.4	55.3	141.7	133.8	3.4	3.0
SN 606	55.6	55.4	120.3	114.9	2.9	2.6
E – 8	56.3	56.0	109.2	105.3	2.6	2.5
LSD ($P \leq 0.5$)	0.4	0.2	5.2	2.9	0.02	0.04

WAP: Weeks after planting

Though increasing planting density of sesame from 66,666 plants ha^{-1} to 133,333 plants ha^{-1} did not significantly ($P \leq 0.05$) affect number of sesame leaves per plant, however the number of total branches per sesame plant at maturity and number of capsules per branch significantly ($P \leq 0.05$) decreased as planting density of sesame in the maize-sesame intercrop increased (Table 5). The number of total branches per sesame plant at maturity, number of sesame leaves per plant and number of capsules per branch were highest from sesame variety 'Ex Sudan' (Table 5).

Sowing sesame variety 'Ex Sudan' into maize at the density of 66,666 plants ha^{-1} produced the highest number of total branches per sesame plant at maturity, highest number of sesame leaves per plant and highest number of capsules per branch (Table 6). Sesame variety 'Ex Sudan' sown into maize at the lowest density of 66,666 plants ha^{-1} could have benefitted maximally from the available growth resources as compared to other intercrop treatments.

In addition, the tallest plants produced by variety 'Ex Sudan' might have enhanced high phothosynthetic absorption of light, thus producing the highest number of total branches per plant at maturity and highest number of leaves per plant. Ozer (2003) reported that increase in branching could be a major cause in the increase in number of leaves.

Increasing planting density of sesame up to 133,333 plants ha^{-1} significantly ($P \leq 0.05$) reduced number of capsules per plant, length of capsule and weight of capsule per plant (Table 7). The greater interspecific competition for nutrients occurring at higher densities of sesame in the intercrop could be responsible for the reduction in number of capsules per plant, length of capsule and weight of capsule per plant. In both years, sesame variety 'Ex Sudan' sown into maize at the density of 66,666 plants ha^{-1} produced the highest number of capsules per plant (79.6 and 85.4 respectively, in years 2014 and 2015), highest capsule length and highest weight of capsule per plant (Table 8).

The highest number of total branches produced per sesame plant could be linked to the highest number of capsules obtained per plant.

Table 4. Interaction of planting densities of sesame x varieties of sesame on days to attain 50 % flowering for sesame, plant height of sesame at maturity and number of primary branches per plant at 9 WAP in a maize-sesame intercrop, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	**Varieties of sesame**	**Days to attain 50 % flowering for sesame**		**Plant height (cm) of sesame at maturity**		**Number of primary branches per plant at 9 WAP**	
		2014	**2015**	**2014**	**2015**	**2014**	**2015**
66,666	Ex Sudan	56.1	56.2	171.4	169.2	3.8	3.4
	SN 603	56.4	56.2	139.1	136.0	3.2	3.2
	E-8	56.5	56.6	129.0	125.8	3.0	3.1
88,888	Ex Sudan	54.0	54.1	145.7	138.8	3.0	2.9
	SN 603	54.9	54.6	120.2	127.3	2.4	2.6
	E-8	55.1	55.3	110.0	114.6	2.0	2.3
133,333	Ex Sudan	55.9	55.6	100.6	93.5	2.8	2.6
	SN 603	55.8	55.6	90.1	81.6	2.4	2.2
	E-8	56.0	56.2	81.0	75.6	2.0	2.1
	LSD ($P \leq 05$)	0.3	0.5	6.3	4.6	0.03	0.07

WAP: Weeks after planting.

Table 5. Main effects of planting densities of sesame and varieties of sesame on number of total branches per sesame plant at maturity, number of sesame leaves per plant and number of capsules per branch, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	**Number of total branches per sesame plant at maturity**		**Number of sesame leaves per plant**		**Number of capsules per branch**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
66,666	7.5	7.2	48.8	44.6	10.4	8.1
88,888	7.0	6.8	40.2	37.7	7.2	6.5

133,333	6.2	6.0	38.2	36.3	6.1	5.1
LSD ($p \leq 0.05$)	0.1	0.3	12.4	14.6	0.5	0.3
Varieties of sesame						
Ex Sudan	7.8	7.4	46.5	42.0	10.2	8.3
SN 603	6.8	6.6	40.3	37.5	7.4	6.5
E-8	6.2	6.0	36.2	34.0	5.2	4.9
LSD ($P \leq 0.05$)	0.2	0.3	2.0	1.1	0.5	0.3

Table 6. Interaction of planting densities of sesame x varieties of sesame on number of total branches per sesame plant at maturity, number of sesame leaves per plant and number of capsules per branch, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Varieties of sesame	Number of total branches per sesame plant at maturity		Number of sesame leaves per plant		Number of capsules per branch	
		2014	2015	2014	2015	2014	2015
66,666	Ex Sudan	10.3	8.0	52.8	48.1	12.6	10.6
	SN 603	7.2	7.0	46.4	44.0	9.2	8.0
	E-8	5.1	6.5	42.2	41.6	6.0	5.6
88,888	Ex Sudan	9.4	7.6	47.4	42.2	10.8	8.2
	SN 603	7.2	6.8	40.1	38.0	7.4	6.2
	E-8	7.0	6.1	35.2	33.1	5.3	5.0
133,333	Ex Sudan	8.4	6.7	40.4	35.8	8.4	6.1
	SN 603	7.2	6.1	32.2	30.7	5.3	5.2
	E-8	5.1	5.4	27.1	27.4	4.3	4.1
	LSD ($P \leq 0.05$)	0.8	0.5	3.2	2.0	0.7	0.5

Table 7. Main effects of planting densities of sesame and varieties of sesame on number of capsules per plant, length (cm)of capsules and weight (kg) of capsules per plant, in years 2014 and 2015, at Makurdi, Nigeria.

Planting densities of sesame	**Number of capsules per plant**		**Length (cm) of capsule**		**Weight (kg) of capsule per plant**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
66,666	72.6	69.8	2.s6	2.8	0.64	0.52
88,888	58.2	55.4	2.2	2.4	0.36	0.34
133,333	34.1	32.2	1.7	2.1	0.23	0.21
LSD ($P \leq 0.05$)	5.4	3.7	0.3	0.2	0.04	0.01
Varieties of sesame						
Ex Sudan	70.5	62.7	2.8	2.6	0.63	0.54
SN 603	55.3	51.7	2.4	2.2	0.33	0.32
E-8	45.1	43.0	1.3	1.5	0.31	0.30
LSD ($P \leq 0.05$)	7.2	2.6	0.3	0.1	0.06	0.04

Similarly, the highest number of capsules produced per plant could be responsible for the highest weight produced. Number of seeds per capsule, weight of 100 seeds and sesame seed yield significantly ($P \leq 0.05$) decreased as density of sesame in the intercrop increased (Table 9).

Kulter *et al.* (2001) in melon production reported that as plant population decreased, yield increased. The highest number of capsules per plant could be linked to the highest number of seeds per capsule and highest yield.

Sesame variety 'Ex Sudan' produced the highest seed yield of 0.45 t ha^{-1} and 0.33 t ha^{-1} respectively, in years 2014 and 2015 (Table 9). The yield produced from sesame variety 'Ex Sudan' was significantly ($P \leq 0.05$) increased by 28.9 % and 27.3 % respectively, in years 2014 and 2015 as compared to that obtained from sesame variety 'SN 603', and by 48.9 %

and 39.4 % respectively, in years 2014 and 2015 as compared to that obtained from the commonly grown sesame variety 'E-8'.

Sesame variety 'Ex Sudan' sown into maize at the density of 66,666 plants ha^{-1} gave the highest number of seeds per capsule, highest weight of 100 seeds and highest sesame seed yield (Table 10).

3. 4. Growth and yield of maize in a maize-sesame intercrop as influenced by planting densities and varieties of sesame

In both years, maize sown in intercrop with the commonly grown sesame variety 'E-8' took significantly ($P \leq 0.05$) more days to attain 50 % flowering compared to when intercropped with the other sesame varieties (Table 11). This could be due to the greater competitive ability and aggressivity of the popularly grown sesame variety 'E-8' in intercrop with maize as compared to the other intercropped sesame varieties.

Table 8. Interaction of planting densities of sesame x varieties of sesame on number of capsules per plant, length (cm) of capsule and weight (kg) of capsules per plant, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Varieties of sesame	Number of capsules per plant		Length (cm) of capsule		Weight (kg) of capsules per plant	
		2014	2015	2014	2015	2014	2015
	Ex Sudan	79.6	85.4	2.80	2.78	0.74	0.62
66,666	SN 603	60.2	66.7	2.60	2.55	0.58	0.52
	E-8	52.0	57.3	2.18	2.16	0.40	0.42
88,888	Ex Sudan	70.4	65.8	2.50	2.43	0.50	0.48
	SN 603	58.0	55.9	2.34	2.30	0.34	0.31
	E-8	48.0	44.6	1.90	1.82	0.21	0.23
133,333	Ex Sudan	35.6	36.9	2.40	2.32	0.35	0.31
	SN 603	30.2	32.5	1.79	1.65	0.23	0.21
	E-8	24.0	27.1	1.54	1.58	0.15	0.12
	LSD ($P \leq 0.05$)	4.1	4.8	0.23	0.21	0.05	0.03

Table 9. Main effects of planting densities of sesame and varieties of sesame on number of seeds per capsule, weight (g) of 100 seeds and sesame seed yield (t ha^{-1}), in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Number of seeds per capsule		Weight (g) of 100 seeds		Sesame seed yield (t ha^{-1})	
	2014	2015	2014	2015	2014	2015
66,666	70.8	64.1	0.55	0.44	0.43	0.35
88,888	52.1	48.5	0.42	0.38	0.28	0.25
133,333	36.2	33.0	0.32	0.27	0.20	0.17
LSD ($P \leq 0.05$)	4.7	6.5	0.06	0.02	0.06	0.03
Varieties of sesame						
Ex Sudan	64.4	56.7	0.59	0.47	0.45	0.33
SN 603	54.2	48.6	0.42	0.34	0.32	0.24
E-8	43.4	40.3	0.31	0.29	0.23	0.20
LSD ($P \leq 0.05$)	6.2	5.9	0.05	0.02	0.04	0.01

Table 10. Interaction of planting densities of sesame x varieties of sesame on number of seeds per capsule, weight (g) of 100 seeds and sesame seed yield (t ha^{-1}), in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities	Varieties of sesame	Number of seeds per capsule		Weight(g) of 100 seeds		Sesame seed yield (t ha^{-1})	
		2014	2015	2014	2015	2014	2015
	Ex Sudan	85.4	79.1	0.62	0.55	0.50	0.44
66,666	SN 603	72.2	61.6	0.50	0.41	0.38	0.34
	E-8	56.0	51.5	0.41	0.36	0.32	0.29
	Ex Sudan	60.6	54.7	0.54	0.46	0.41	0.34
88,888	SN 603	52.4	49.5	0.42	0.36	0.21	0.23
	E-8	46.2	41.4	0.35	0.32	0.17	0.19

	Ex Sudan	42.2	36.3	0.43	0.39	0.25	0.21
133,333	SN 603	38.2	34.6	0.32	0.26	0.20	0.17
	E-8	32.0	28.0	0.21	0.17	0.16	0.12
	LSD ($P \leq 0.05$)	5.2	3.0	0.08	0.03	0.05	0.03

Table 11. Main effects of planting densities of sesame and varieties of sesame on days to attain 50 % flowering for maize, maize plant height (cm) at 50 % flowering and stem diameter (mm) of maize plant at 6 WAP, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	**Days to attain 50 % flowering for maize**		**Maize plant height (cm) at 50 % flowering**		**Stem diameter (mm) of maize plant at 6 WAP**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
66,666	46.3	46.1	346.4	339.3	25.1	23.3
88,888	47.2	47.0	320.5	311.7	20.3	19.4
133,333	47.9	48.1	270.2	266.6	10.3	11.4
LSD ($P \leq 0.05$)	0.24	0.27	5.8	7.6	2.1	0.9
Varieties of sesame						
Ex Sudan	45.6	45.8	351.2	342.6	26.4	22.2
SN 603	46.6	47.1	317.4	303.6	20.1	17.4
E-8	48.4	48.2	280.0	271.4	15.3	14.4
LSD ($P \leq 0.05$)	0.20	0.24	6.8	8.7	2.4	0.7

WAP: weeks after planting

Maize plant height at 50 % flowering and stem diameter of maize at 6 WAP significantly ($P \leq 0.05$) reduced as density of sesame increased up to 133,333 plants ha^{-1} (Table 11). Muoneke and Asiegbu (1997) reported that high plant density of crops reduced plant height due to competition for light. The interaction of planting densities and varieties of sesame showed that irrespective of the planting densities, more days was taken for maize to attain 50 % flowering when in intercrop with the popularly grown sesame variety 'E-8' (Table 12). The tallest maize height and increased stem diameter for maize at 6 WAP (26.3 cm and 27.4 cm respectively, in years 2014 and 2015) were obtained from intercropped maize with sesame variety 'Ex Sudan' sown at the density of 66,666 plants ha^{-1} (Table 12). This could be attributed to the more efficient use of basic resources absorbed at the lowest density of 66,666 plants ha^{-1}. This view agrred with Ogindo and Walker (2005) who reported that improvement of water use efficiency in intercropping leads to greater use of other resources.

Stem diameter of maize at 12 WAP, number of leaves per maize plant at 50 % flowering and leaf area index of maize at 50 % flowering significantly ($P \leq 0.05$) reduced as the density of sesame increased up to 133,333 plants ha^{-1} (Table 13). The intense competition for available resources occurring at highest plant density of intercropped sesame could have induced the reduction in stem diameter of maize at 12 WAP, number of maize leaves and leaf area index. The highest stem diameter of maize at 12 WAP, highest number of leaves per maize plant and highest leaf area index (LAI) of maize were obtained intercropping with sesame variety 'Ex Sudan' at the density of 66,666 plants ha^{-1} (Table 14). Number of cobs per plant, cob length and cob diameter at maturity reduced with increase in planting density of sesame (Table 15). This view agreed with Kulter *et al*. (2001) who reported that as plant population per hectare increased, number of fruits per plant decreased.

Table 12. Interaction of planting densities of sesame x varieties of sesame on days to attain 50 % flowering for maize, maize plant height (cm) at 50 % flowering and stem diameter (mm) of maize plant at 6 WAP, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Varieties of sesame	Days to attain 50 % flowering for maize		Maize plant height (cm) at 50% flowering		Stem diameter (mm) of maize plant at 6 WAP	
		2014	2015	2014	2015	2014	2015
	Ex Sudan	45.1	45.3	380.6	359.0	26.3	27.4
66,666	SN 603	45.8	46.1	347.2	335.0	21.2	22.8
	E-8	46.5	46.9	320.4	323.8	17.4	19.6
	Ex Sudan	45.5	45.7	355.7	341.5	25.4	24.1
88,888	SN 603	46.7	47.0	330.0	321.8	20.2	18.8
	E-8	47.9	48.0	280.2	272.0	17.1	15.1
	Ex Sudan	45.7	46.3	350.4	327.3	16.0	15.2
133,333	SN 603	47.9	48.3	262.1	254.0	12.0	10.5
	E-8	49.5	49.7	229.4	218.5	9.0	8.5
	LDS($P \leq 0.05$)	0.45	0.41	5.7	2.7	2.4	1.3

WAP: Weeks after planting

Table 13. Main effects of planting densities of sesame and varieties of sesame on stem diameter (mm) of maize plant at 12 WAP, number of leaves per maize plant at 50 % flowering and leaf area index of maize at 50 % flowering, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Stem diameter (mm) of maize plant at 12 WAP		Number of leaves per maize plant at 50 % flowering		Leaf area index (LAI) of maize at 50% flowering	
	2014	2015	2014	2015	2014	2015
66,666	48.4	46.1	14.9	13.7	3.85	3.77
88,888	37.5	38.6	10.4	11.8	3.20	3.16
133,333	30.3	28.6	9.4	10.1	2.60	2.57
LSD($P \leq 0.05$)	0.85	0.79	0.40	0.34	0.15	0.10
Varieties of sesame						
Ex Sudan	49.6	45.4	14.2	13.0	3.70	3.69
SN 603	40.2	37.1	10.9	11.8	3.14	3.09
E-8	32.4	30.8	9.8	10.9	2.64	2.71
LSD($P \leq 0.05$)	0.43	0.65	0.18	0.12	0.10	0.08

WAP: Weeks after planting.

Table 14. Interaction of planting densities of sesame x varieties of sesame on stem diameter (mm) of maize plant at 12 WAP, number of leaves per maize plant at 50 % flowering and leaf area index (LAI) of maize at 50 % flowering, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Varieties of sesame	Stem diameter (mm) of maize plant at 12 WAP		Number of leaves per maize plant at 50 % flowering		LAI of maize at 50 % flowering	
		2014	2015	2014	2015	2014	2015
66,666	ExSudan	58.8	51.5	14.9	14.7	3.96	4.13
	SN 603	50.2	46.3	13.4	13.3	3.50	3.78
	E-8	45.0	40.5	12.2	12.0	3.21	3.40

	Ex Sudan	50.8	46.7	13.6	13.2	3.75	3.68
88,888	SN 603	40.2	37.7	11.5	11.8	3.20	3.13
	E-8	32.4	31.3	11.0	10.5	2.71	2.68
	Ex Sudan	42.3	38.0	11.4	11.2	3.35	3.28
133,333	SN 603	31.2	27.2	9.8	10.1	2.45	2.38
	E-8	23.6	20.7	9.2	9.1	2.13	2.05
	LSD ($P \leq 0.05$)	3.41	1.13	0.40	0.36	0.22	0.14

WAP; Weeks after planting

Table 15. Main effects of planting densities of sesame and varieties of sesame on number of cobs per plant, cob length (cm) at maturity and cob diameter (cm) at maturity, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	**Number of cobs per plant**		**Cob length (cm) at maturity**		**Cob diameter (cm) at maturity**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
66,666	1.7	1.9	17.2	16.7	13.7	14.9
88,888	1.4	1.6	16.0	15.6	10.5	12.8
133,333	1.2	1.4	15.0	15.3	8.0	10.7
LSD ($P \leq 0.05$)	0.11	0.14	0.4	0.2	2.1	1.8
Varieties of sesame						
Ex Sudan	2.2	2.0	15.8	16.1	14.5	13.3
SN 603	1.8	1.6	15.4	15.8	11.2	12.4
E–8	1.2	1.3	15.1	15.6	9.1	11.7
LSD ($P \leq 0.05$)	0.12	0.08	5.2	8.3	10.8	6.2

Highest number of cobs per plant, highest cob length and highest cob diameter were obtained from maize in intercrop with sesame variety 'Ex Sudan' sown at the density of

66,666 plants ha^{-1} (Table 16). Cob weight at maturity, weight of 1000 grains and grain yield of maize significantly ($P \leq 0.05$) increased at the lowest sesame density of 66,666 plants ha^{-1} (Table 17). Experiments with wide range of densities in melon production had shown that as plant population per hectare reduced, the fruit weight per plant and yield increased (Kulter *et al*., 2001). In both years, the highest grain yield from intercropped maize was obtained when sesame variety 'Ex Sudan' was sown in the intercrop.

Intercropping maize with sesame variety 'Ex Sudan', significantly ($P \leq 0.05$) increased grain yield of maize (35.1 % and 22.9 % respectively, in years 2014 and 2015) compared to that obtained from maize in intercrop with sesame variety 'SN 603', and by 51.4 % and 40.0 % respectively, in years 2014 and 2015, as compared to that produced from maize in intercrop with the popularly grown sesame variety 'E-8' (Table 17). The interaction of planting densities of sesame x varieties of sesame showed that the highest grain yield of maize was obtained from intercropped maize with sesame variety 'Ex Sudan' sown at the density of 66,666 plants ha^{-1} (Table 18).

The tallest maize height, highest leaf area index (LAI), highest number of cobs per plant and highest cob weight obtained from intercropped maize with sesame variety 'Ex Sudan' sown at the lowest density of 66,666 plants ha^{-1} could be responsible for the highest grain yield of maize obtained at that interaction level. This view supports Suleiman (2005) who observed a correlation between plant height and yield. Sesame variety 'Ex Sudan' is observed to be the most suitable and compatible intercrop with maize. Awal *et al*. (2006) stated that crop compatibility is the most essential factor for a feasible intercropping system. A careful selection of compatible varieties could reduce competition to a considerable extent (Ofori and Stern, 1986).

Table 16. Interaction of planting densities of sesame x varieties of sesame on number of cobs per plant, cob length (cm) at maturity and cob diameter (cm) at maturity, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Varieties of sesame	Number of cobs per plant		Cob length (cm) at maturity		Cob diameter (cm) at maturity	
		2014	2015	2014	2015	2014	2015
	Ex Sudan	2.6	2.3	18.4	17.1	15.4	14.8
66,666	SN 603	2.0	1.8	15.4	16.6	12.4	13.7
	E-8	1.4	1.6	15.0	16.4	11.2	13.5
	Ex Sudan	1.8	2.0	15.4	15.7	11.0	13.7
88,888	SN 603	1.2	1.6	14.2	15.6	9.4	12.8
	E-8	1.0	1.3	13.1	15.5	9.0	12.0
	Ex Sudan	1.5	1.7	15.4	15.6	9.3	11.5

133,333	SN 603	1.2	1.3	14.1	15.3	8.0	10.8
	E-8	1.0	1.1	13.1	15.0	7.2	9.7
	LSD ($P \leq 0.05$)	0.13	0.17	0.6	0.4	0.7	0.4

Table 17. Main effects of planting densities of sesame and varieties of sesame on weight (g) of 1000 grains, cob weight (g) at maturity and grain yield (t ha^{-1}) of maize, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	**Weight (g) of 1000 grains**		**Cob weight (g) at maturity**		**Grain yield (t ha^{-1})**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
66,666	135.7	130.3	290.6	286.9	3.6	3.8
88,888	112.3	110.4	278.2	273.0	2.8	2.6
133,333	100.2	99.7	261.0	256.4	1.6	1.9
LSD ($P \leq 0.05$)	5.1	8.4	10.1	4.8	0.21	0.24
Varieties of sesame						
Ex Sudan	128.6	123.8	296.2	299.5	3.7	3.5
SN603	115.4	113.8	272.1	269.3	2.4	2.7
E-8	100.1	102.8	250.4	247.6	1.8	2.1
LSD ($P \leq 0.05$)	8.0	9.1	10.6	5.3	0.24	0.11

Table 18. Interaction of planting densities of sesame x varieties of sesame on weight (g) of 1000 grains, cob weight (g) at maturity and grain yield (t ha^{-1}), in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	**Varieties of sesame**	**Weight (g) of 1000 grains**		**Cob weight (g) at maturity**		**Grain yield (t ha^{-1})**	
		2014	2015	2014	2015	2014	2015
	Ex Sudan	142.4	139.6	322.8	315.1	4.0	4.2

66,666	SN 603	132.2	130.4	290.4	284.5	3.6	3.8
	E-8	125.0	120.8	270.2	261.1	3.2	3.3
	Ex Sudan	125.5	119.3	300.6	298.9	3.6	3.5
88,888	SN 603	115.0	112.9	280.2	271.4	2.6	2.4
	E-8	94.0	99.0	251.2	248.8	2.0	1.8
	Ex Sudan	120.6	112.5	288.3	284.4	2.5	2.7
133,333	SN 603	100.4	98.0	260.0	252.1	2.0	1.8
	E-8	92.0	88.6	241.2	232.8	1.4	1.3
	LSD ($P \leq 0.05$)	6.4	4.6	6.3	8.4	0.22	0.26

The compatibility of sesame variety 'Ex Sudan' could also be due to its genetic composition and tolerant response to the environmental condition of the study location.

The highest biomass weight for maize (leaf dry weight and stem dry weight) were achieved sowing sesame variety 'Ex Sudan' in the intercrop at the density of 66,666 plants ha^{-1} (Table 19). This could be linked to the significant increase in the number of leaves, leaf area and stem diameter.

3. 5. Evaluation of yield advantages of maize-sesame intercrop as influenced by planting densities of sesame and varieties of sesame

The intercrop yields were lower than the sole crop yields (Table 20). The reduction in the intercropped yields as compared to sole crop yields could be attributed to the inter-specific competition and increased demands for growth resources occurring in intercropping. This view agreed with Olufajo (1992) who reported higher yields in sole cropping over intercropping. Irrespective of the planting densities of sesame and varieties of sesame, total intercrop yields were greater than the intercrop yields of component crops (Table 20).

The highest land equivalent ratio (LER) values of 1.83 and 1.80 respectively recorded in years 2014 and 2015 were obtained from the intercrop of maize with sesame variety 'Ex Sudan' sown at the density of 66,666 plants ha^{-1}, thereby saving 45.4 % and 44.4 % of land in years 2014 and 2015, which could be used for other agricultural purposes (Table 21). It is most advantageous to have both crops in intercrop at this level of interaction. This could be due to greater level of resource utilization at the treatment level. Hiebsch and McCollum (1987) reported that LER greater than 1.00, could be due to greater efficiency of resource utilization in intercropping. The highest land equivalent coefficient (LEC) values of 0.84 and 0.81 respectively recorded in years 2014 and 2015 at the same interaction level agreed with Adetiloye *et al*. (1983) who reported that for a two crop mixture, the minimum expected productivity coefficient is 0.25 (Table 21).

Table 19. Interaction of planting densities of sesame x varieties of sesame on biomass weight (leaf dry weight and stem dry weight) of maize plant, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Varieties of sesame	Biomass weight(g)			
		Leaf dry weight		Stem dry weight	
		2014	2015	2014	2015
66,666	Ex Sudan	248.0	256.2	359.0	365.3
	SN 603	231.6	235.4	335.0	340.2
	E- 8	219.1	225.0	323.8	330.0
88,888	Ex Sudan	233.7	248.4	341.5	352.2
	SN 603	216.1	225.0	321.8	325.2
	E-8	187.6	194.2	272.0	284.6
133,333	Ex Sudan	219.3	226.6	327.3	325.4
	SN 603	156.0	167.4	254.0	260.0
	E-8	101.8	120.7	218.5	225.4
	LSD ($P \leq 0.05$)	5.4	7.2	4.1	8.3

Table 20. Sole crop yields, intercrop yields and total intercrop yields as affected by the interaction of planting densities of sesame x varieties of sesame in a maize-sesame intercrop, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	Varieties of sesame	Sole crop yields ($t\ ha^{-1}$)				Intercrop yields ($t\ ha^{-1}$)				Total inter crop yields ($t\ ha^{-1}$)	
		Maize		Sesame		Maize		Sesame			
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
	Ex Sudan	–	–	–	–	4.0	4.2	0.50	0.44	4.50	4.64
66,666	SN 603	–	–	–	–	3.6	3.8	0.38	0.34	3.98	4.14

	E-8	–	–	–	–	3.2	3.3	0.32	0.29	3.52	3.59
88,888	Ex Sudan	–	–	–	–	3.6	3.5	0.41	0.34	4.01	3.84
	SN 603	–	–	–	–	2.6	2.4	0.21	0.23	2.81	2.63
	E-8	–	–	–	–	2.0	1.8	0.17	0.19	2.17	1.99
133,333	Ex Sudan	–	–	–	–	2.5	2.7	0.25	0.21	2.75	2.91
	SN 603	–	–	–	–	2.0	1.8	0.20	0.17	2.20	1.97
	E-8	–	–	–	–	1.4	1.3	0.16	0.12	1.56	1.42
	Soles	4.6	4.8	0.52	0.48	–	–	–	–	–	–

Table 21. Evaluation of yield advantages of maize-sesame intercrop as influenced by the interaction of planting densities of sesame x varieties of sesame, in years 2014 and 2015 at Makurdi, Nigeria.

Planting densities of sesame	**Varieties of sesame**	**Lm**		**Ls**		**LER**		**CR**		**% Land saved**		**Aggressivity**		**LEC**	
		2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
	Ex Sudan	0.87	0.88	0.96	0.92	1.83	1.80	0.91	0.96	45.4	44.4	-0.09	-0.04	0.84	0.81
66,666	SN 603	0.78	0.79	0.73	0.71	1.51	1.50	1.07	1.11	33.8	33.3	0.05	0.08	0.57	0.56
	E -8	0.70	0.69	0.62	0.60	1.32	1.29	1.13	1.15	24.2	22.5	0.08	0.09	0.43	0.41
	Ex Sudan	0.78	0.73	0.79	0.71	1.57	1.44	0.98	1.03	36.3	30.6	-0.01	0.02	0.62	0.52

	133,333			88,888
E -8	SN 603	Ex Sudan	E -8	SN 603
0.30	0.43	0.54	0.43	0.57
0.27	0.38	0.56	0.38	0.50
0.31	0.38	0.48	0.33	0.40
0.25	0.35	0.44	0.40	0.48
0.61	0.81	1.02	0.76	0.97
0.52	0.73	1.00	0.78	0.98
0.97	1.13	1.13	1.30	1.43
1.08	1.09	1.27	0.95	1.04
-63.9	-23.5	2.00	-31.6	-3.10
-92.3	-37.0	0.00	-28.2	-2.00
-0.01	0.05	0.06	0.10	0.17
0.02	0.03	0.12	-0.02	0.02
0.09	0.16	0.26	0.14	0.23
0.07	0.13	0.25	0.15	0.24

The lowest competitive ratios (CR) and lowest aggressivity were recorded from the intercrop of maize with sesame variety 'Ex Sudan' sown at the density of 66,666 plants ha^{-1}. At this interaction level, both crops can be termed to have dominated each other (Table 21).

4. CONCLUSION

From the results obtained, it can be concluded that the highest sesame seed yield, highest maize grain yield, highest land equivalent ratio (LER) values and highest land equivalent coefficient (LEC) values were obtained intercropping maize with sesame variety 'Ex Sudan' sown at the density of 66,666 plants ha^{-1}. This level of treatment also recorded the lowest competitive ratio and lowest aggresivity, were both component crops in the intercrop dominated each other.

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